



Home moisture problems

D.M. Brook

Moisture problems can occur in many places in homes for many reasons: when high levels of moisture enter building cavities or get inside, when excessive moisture is produced indoors, or when indoor air comes into contact with cold surfaces such as single-pane windows or uninsulated walls. Excess moisture often originates outside the structure, as with foundation drainage problems, or it may be the result of activities by the occupants indoors. Cold surfaces usually are the result of air leakage or inadequate insulation in building cavities, or in rooms where less heat is provided in the winter.

Solving home moisture problems usually starts with a little detective work—looking for moisture sources outside the house and determining how to control them, minimizing production of humidity inside the house, and installing ventilation where needed. Localized moisture problems often can be solved by warming up interior surfaces. In some cases, moisture problems may be not be easily or cheaply solved, and use of a dehumidifier or whole-house ventilation system may be part of the solution.

What causes moisture problems?

The amount of water vapor that air can hold depends on its temperature. Since warm air can hold far more moisture than cold air, we talk about “relative humidity” (RH). During the winter, condensation occurs when warm indoor air is cooled down as it comes into contact with a cold surface, such as a single-pane window or an uninsulated wall. Since the moisture-holding capacity of the cool air is less than that of warm air, the excess moisture condenses, usually on the

first cold surface. The temperature at which the air can hold no additional moisture is called the “dew point.”

Indoor humidity is the result of the amount of moisture produced inside, the relative humidity of the air outdoors, and the building air-exchange rate. Depending on the building air-exchange rate, the same amount of moisture may cause no moisture problems in one house, while resulting in serious mold and mildew in another. In coastal areas, where the outside relative humidity may be quite high year round, outside ventilation air may produce little drying effect.

Lack of humidity can be a problem in houses with very high air-exchange rates. Houses “dry out” when cold winter air enters the house through infiltration and is warmed up by the heating system. Since the total amount of moisture cold air can hold is small even at 100 percent RH, when it is warmed up indoors, its relative humidity is lower and it feels dry to us. This is why houses with serious air leakage problems in areas east of the Cascades often require humidifiers to maintain a comfortable level of indoor humidity. After weatherization or in new construction, houses should not require humidifiers to maintain 30 to 50 percent RH, which minimizes indoor air pollution problems and which most people find comfortable.

Indoor relative humidity levels between 30 and 50 percent RH are comfortable for most people, and minimize health and

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David M. Brook, Extension agent, Multnomah County, Oregon State University.



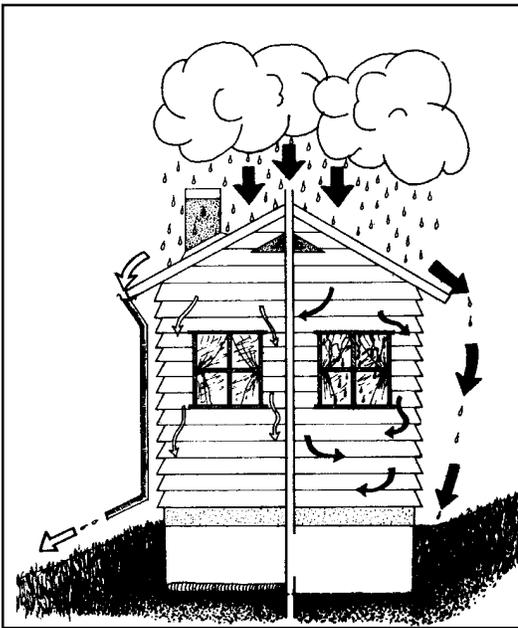


Figure 1.—Gutters, a slope away from the house, and drainage tile in the foundation keep the left side of this house dry. No gutters, a slope toward the house, and no drainage tile expose the right side to moisture damage.

structural moisture problems. High humidities lead to mold, mildew, and high concentrations of biological microorganisms such as bacteria and dust mites, which can affect the health of occupants. Condensation causes discoloration of ceilings and walls. High humidity in the building's structural cavities, such as attics, walls, and foundation area, can lead to wood decay and eventually structural failure. If the wintertime relative humidity is above 50

percent, you should take steps to control sources of excess moisture in your home as described in this publication. Low indoor humidity may prevent moisture problems in localized areas, such as closets or building cavities, but it doesn't ensure that moisture problems won't occur elsewhere in the house.

When you understand the sources of the moisture in your home and the way moisture moves, you should be able to effectively control it.

Symptoms of excess indoor moisture

Many signs of moisture problems and excess moisture are readily apparent while others are difficult to detect. Here are some common clues of indoor moisture problems:

Odors. Odors increase in intensity with high relative humidity. Musty smells may signal mold, mildew, or rot. Everyday household odors that seem to linger may be a signal of too much moisture in the air.

Frost and ice on cold surfaces. Frost or ice on windows, attic framing, or any surface is an indication of trouble. Condensation can be a sign of excess moisture in the air, indicating a need to stop air leaks cooling the cavity or to warm the surface with insulation.

Damp feeling. The sensation of dampness is common in areas with high humidity.

Surface discoloration, staining, texture changes. These usually indicate some moisture damage, no matter what the material. These changes may appear as black or dark streaks or lines bordering a discoloration. The area may or may not feel wet.

Mold and mildew often appear as a discoloration, which may be white, orange, green, brown, or black. Surface conditions that may indicate decay often are noticed as a musty odor. They can be found under carpets, behind cupboards, on framing between subfloors, in crawl spaces, and in attics. Mold and mildew can get a start whenever the relative humidity of air near a surface is above 70 percent RH. They grow fastest at temperatures above 40°F.

Deformed wood surfaces. Wood swells when it becomes wet, and warps, cups, and cracks when it dries.

Wood decay. Wood rot and decay indicate advanced moisture damage. Unlike surface mold and mildew, wood decay fungi penetrate the wood and make it soft and weak. Look for any type of rot or mushroom-like growths. (See page 11 for more information on detecting wood decay.)

Sweating pipes, water leaks, and dripping. Water vapor may condense and drip off cold pipes, or the pipes may be leaking.

Peeling, blistering, cracking paint. Moisture may be moving from outside or inside the home to damage paint.

Crusty, powdery, chipping concrete and masonry. A buildup of salt or other powdery substance indicates that water has evaporated after moisture has moved through it. Freeze-thaw cycles speed the process of deterioration, causing chipping and crumbling.

High indoor humidity. Indoor humidity levels are best when maintained between 30 and 50 percent RH. They can easily be measured with a "hygrometer"—a low-cost relative humidity indicator, sometimes coupled with a thermometer, available at hardware stores and home centers. Remember, low indoor humidity does not ensure the absence of moisture problems elsewhere in the house.

Outdoor sources of moisture

Poor foundation drainage around the house often is the major source of exterior moisture getting into the house (Figure 1). Proper drainage is a critical first line of defense against moisture problems. Precipitation, surface water, ground water table, and outdoor water use can change seasonally, creating problems that may show only at certain times in the year.

Foundation drainage. Plugged downspouts and blocked foundation footing drains are common sources of outdoor moisture getting into the house. If indoor moisture problems suddenly develop, these areas are prime suspects. Ground sloping toward the house also may contribute to wet basements or crawl spaces.

Slabs. If no moisture barrier was installed underneath the slab when it was poured, water in the ground may permeate through it and then evaporate into the air inside the house. This often is the source of the problem when a garage has been converted to living space.

Below-grade walls. Moisture may move up through cement block foundations, dampening the walls above and raising indoor humidity levels even though the basement or crawl space is dry. If ground water is a suspect, use the capillary test on page 4 to determine if moisture is wicking up through the ground and coming from the interior space.

Splashback. When siding is within 12 inches of the ground, raindrops can splash upward, soaking the bottom edge of the siding. This moisture can move into the wall through capillarity, wetting far more than the bottom edge. If there is sufficient slope to the ground around the foundation, remove soil to increase clearance between the siding and grade—2 feet is preferable. The bottom edge of the siding should be painted and sealed to prevent moisture from rising by capillarity. If necessary, install wedges in the siding to provide a capillary break.

Construction details. Flat ledges, inadequate drip edges, and other construction details also can allow exterior moisture to enter the house. Old roof shingles and missing flashing around chimney and plumbing vent stacks may allow moisture into attics or walls for many years before it is discovered.

How moisture gets into houses

- Bulk moisture—in the form of rain, snow or ground water, leaking into basements, crawl spaces, roofs and walls.
- Capillary action—movement of water through a porous material, such as vertical movement through cement block wall, like a sponge or paper towel absorbing moisture.
- Air movement—water vapor transported through air leakage.
- Vapor diffusion—moisture permeating through solid surfaces, such as cement, gypsum board or wood.

Blocked exterior air circulation. Foliage close to the dwelling or items stored next to the house, such as firewood, can block air circulation and cause localized areas of high humidity. Roof and soffit vents can become clogged by dust, leaves, or tree flowers.

Indoor sources of moisture

Many sources of excess moisture can lead to high indoor humidity and cause a wide variety of problems (Figure 2 and table on page 11). Some indoor moisture production is normal. Whenever possible, sources of excess indoor moisture should be removed or vented outside at the source. Check each possible moisture source—the problems may have one or more causes—and take the corrective actions outlined in the table on page 6.

Occupants. Most of the moisture produced indoors in a normal house is a result of normal respiration of people and pets. When there are many occupants in a limited space, such as less than 250 square feet of living space per person, moisture could be a problem.

Domestic activities. Baths and showers, cooking without lids, and hanging wet clothing and towels inside to dry can produce excessive moisture. Uncovered aquariums and large numbers of house plants also produce a considerable amount of moisture.

Clothes dryer vented into the living space. Clothes dryers sometimes are exhausted into the living space to save the heat. This is a very bad idea for both gas and electric dryers. In addition to the excess moisture, air pollution may result from combustion by-products, lint, and residual detergent, fabric softeners, and bleach products vented into

Capillary test

To determine if moisture is coming through the foundation walls or floor to the inside, or whether moisture is coming from inside the dwelling itself, do the following:

- (1) Identify the damp interior surface. Testing of multiple locations on the floor or walls may be necessary to locate external sources of moisture.
- (2) Dry a portion of the damp area approximately 2 feet by 2 feet. (A hair dryer can be used.)
- (3) Cover the dried area with a piece of plastic, firmly attached and sealed with tape around the edges.
- (4) Check the underside of the air-vapor barrier after a couple of days. If there are beads of moisture under the barrier, there is water seeping or wicking through the surface into the dwelling.

However, if the air-vapor barrier is wet on the room side and dry underneath, the dampness is from condensation of room air on the cold surface of the plastic. It is possible for both sides to be damp, which indicates both external seepage and internal condensation problems.

This test sometimes is difficult to interpret. Seasonal variations in surface water flow patterns and the ground water table can cause confusion. You may need professional advice.

the living space. Hanging clothes to dry indoors during the winter has the same effect.

Combustion appliances. Gas ranges, ovens, and unvented kerosene or propane space heaters produce large quantities of moisture—as well as dangerous combustion byproducts—if used extensively without the exhaust fan. In some cases, the chimney for an oil or gas furnace, boiler, or water heater may be blocked by a bird's nest or debris, forcing the exhaust gases into the living space. Corrosion near the flue connection to the furnace or water heater is a sign that exhaust gases are not being vented properly. In other cases, negative pressures may be created in the furnace or water heater area by exhaust fans or forced air ductwork in the house, pulling exhaust gases into the house.

Wood. Storing firewood in the house can lead to problems. Though seemingly dry, wood can contain a great deal of water, which will evaporate into the house as the wood dries.

Attics. Attic bypasses are passageways where warm air escapes from the house into your attic. If water vapor escapes to the attic and is trapped there, it may condense on

surfaces and freeze during cold weather. When it thaws, the water may damage ceilings and walls and contribute to humidity problems. Bypasses can allow enormous amounts of warm, moist air to leak into the attic (Figure 3). These include plumbing chases, spaces around chimneys, up interior walls, and around light fixtures, etc. Sealing them can save on winter heating expenses while preventing moisture damage.

Crawl spaces. If the ground is not covered by a vapor barrier, high humidity can build up in the crawl space. This may lead to wood decay and contribute to high humidity in the house.

Construction materials. Lumber and other building materials used in construction contain a large volume of water, which is released into the house during the first few months as the materials dry. If the house is properly—that is, tightly—built, some steps should be taken to control internal moisture, especially during the first 2 years. Running exhaust fans continuously should help increase the air-exchange rate of the house while the building materials dry out.

Inadequate use of exhaust fans. Poor ventilation of high moisture areas, such as kitchens and baths, commonly leads to damage in those areas. If kitchen and bath fans are not installed or not used, moisture problems may be the first clue. Adequate spot ventilation usually corrects these moisture problems. (See page 7 for information on installing exhaust fans.)

Aquariums and house plants. Tropical fish tanks and extensive indoor house plants can add large amounts of moisture to the air. Unless properly sealed with a vapor barrier, attached greenhouses can cause moisture problems in the wall they share with the house, because of condensation. In addition, drainage may be a problem.

Humidifiers. Continuing to use a humidifier after a house has been weatherized can produce excess moisture since the house air-exchange rate is lower. A humidifier generally is unnecessary in a properly weatherized house. A poorly maintained humidifier also may be a breeding ground for bacteria and other microorganisms.

Air conditioners. Air conditioners cool the air, raising the relative humidity. Occasionally, an air conditioner that has too much capacity for the space it is cooling can make

the problem worse. Air conditioners should be properly sized to avoid this problem.

Plumbing leaks. Sometimes, moisture problems are the result of plumbing leaks causing puddles in a basement or crawl space, or they may be hidden in building cavities such as walls or underneath toilets or bathtubs. One way to check the plumbing is to run each faucet for 5 to 10 minutes while watching and listening for leaks.

Solving home moisture problems

The solution to many indoor moisture problems begins outdoors. Look for sources, mechanisms, and pathways for outdoor moisture to get indoors. These include unclogging downspouts and foundation drains causing a wet basement or crawl space, installing a missing or torn ground moisture barrier in a crawl space, and fixing roof or wall leaks dampening the house framing (see page 8).

Then look for ways to control indoor moisture generation. Hang clothes to dry outside or on a porch. Cover fish tanks. Don't use unvented kerosene space heaters indoors. If you see rust or corrosion near the flue connection of a gas or oil water heater, the chimneys may be blocked. Turn off humidifiers, and don't boil kettles of water on stoves or radiators in the winter.

Finally, use spot ventilation to remove moisture where it is produced. Vent clothes dryers outside. Install and use ducted vent fans to exhaust moisture from the kitchen and bathrooms, where large amounts of moisture may be produced (see page 7).

This three-step approach should control home moisture problems. If it doesn't, consider installing a dehumidifier or a whole-house ventilation system.

If your home moisture problem is localized, the cause may not be excessive humidity, but rather, a cold surface. You can reduce window condensation by installing storm windows, or by replacing single-pane windows with double-pane high performance windows. Mold and mildew on a wall or ceiling may be caused by poor insulation or by significant air leaks, which cool the surface down. Seal outside air leaks and install insulation.

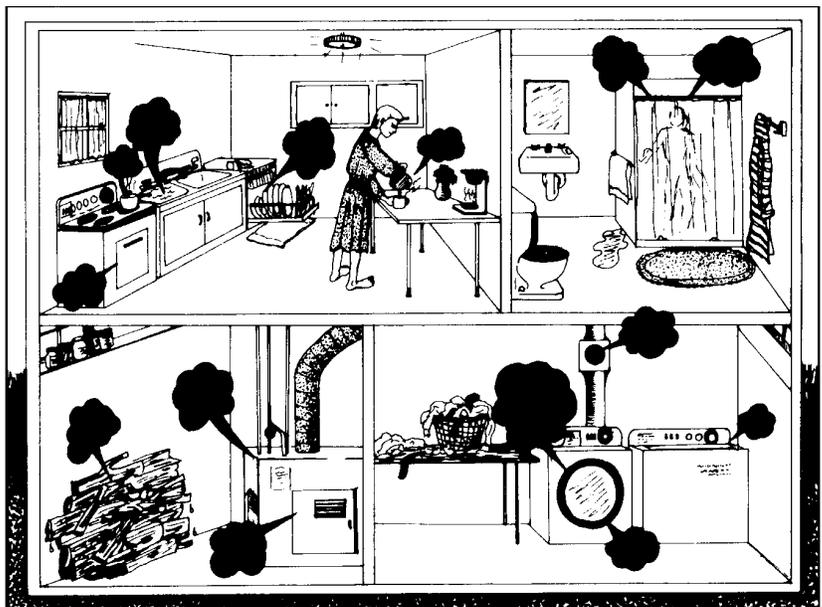


Figure 2.—Common indoor moisture sources.

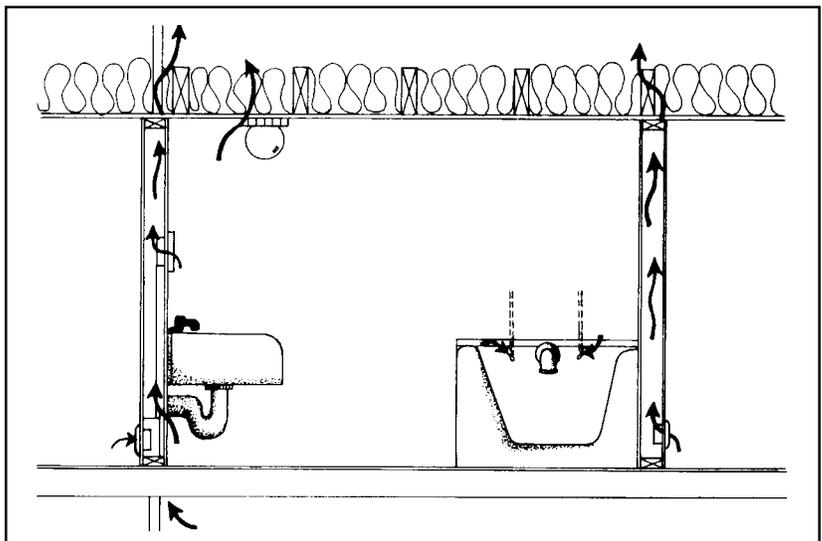


Figure 3.—Attic bypasses.

Three kinds of ventilation

There are three types of ventilation in homes: building cavity ventilation, to control moisture in crawl spaces and attics; spot ventilation, to remove moisture and other indoor pollutants where they are produced; and, if needed, whole-house ventilation, to ensure adequate fresh air for occupants.

Building cavity ventilation. This type of venting may be important for crawl spaces, attics, and other unconditioned spaces. Reducing the entry of moisture into these cavities by sealing air bypasses from inside

Symptoms and solutions to home moisture problems

Symptoms and causes

Possible solutions

Drainage around house

Slope the ground around the foundation so that water will drain away from the house. Check for blocked downspouts and gutters. Install rain gutters where necessary. Check for cracks in foundations, and install proper perimeter footing drains, if necessary.

Inadequate interior ventilation

Install quiet, externally venting fans in kitchens and baths. Become aware of moisture-generating activity and reduce moisture production. If a significant amount of ventilation is needed, a whole-house ventilator system also could be considered.

Inadequate attic or crawl space ventilation

Install any needed vents in attics, crawl spaces and other areas. Check insulation to see if it is blocking ventilation routes.

Many occupants in a small area

Try to reduce interior moisture sources. Add whole-house ventilation. As a last resort, consider dehumidification.

Wood piles

Do not store more than a few days' supply of wood in the house.

Clothes dryer vented into the living space

A very bad idea. While there is a small heat gain, there also is a large amount of moisture and other airborne pollutants. Don't do it.

Cold surfaces, lack of insulation

Seal infiltration leaks first, then insulate, employing proper vapor barrier techniques. Check existing insulation. Insulate windows with additional glazing or other treatments that seal around all edges. For closets or other out-of-the-way places, leave doors open or install louvered doors for better air and heat circulation. A light bulb may warm up a confined space.

New construction, retrofit, remodeling

To speed the drying process, increase ventilation and circulation, both during construction and during the first months of occupancy. Avoid using a humidifier. It may be necessary to dehumidify.

Unvented heaters, faulty heating plants

Check for blocked furnace vents, chimney blockage, a chimney that is too short, insufficient combustion air or whether the system is vented at all—**do not use an unvented kerosene or gas heater indoors.** Make sure your home has an adequate

Symptoms and causes

Possible solutions

supply of combustion air. If you suspect the heating plant is faulty in any way, call for help from the local utility or a heating contractor. **Don't wait.**

Air conditioners, humidifiers

Use humidifiers only when needed. Otherwise, avoid them. An unnecessary central humidification system can be disconnected. The main overall action for air conditioners is to keep the thermostat setting at 75°F or above, to help save cooling dollars and to keep surface temperatures above the point at which condensation will occur. Drain air conditioning condensation to the sewer system or the outdoors, not the crawl space.

Plumbing leaks

Run each part of the plumbing system for 10–15 minutes while watching and listening for leaks. Check all accessible connections. Leaking pipes may be buried in a concrete slab floor or hidden in the house.

House plants, aquariums

Provide adequate air circulation and ventilation. Avoid excessive watering. Keep the greenhouse at recommended humidity levels. If the humidity is high, avoid venting into the home. Provide proper exterior drainage away from the house and the greenhouse. Use proper vapor barrier and insulation techniques.

Dampness or standing water in basement or crawlspace

Add a ground moisture barrier and ventilate the crawl space. Fix basement drainage with drain tiles, drain pipe, or sump pump. Try fixing cracks in the foundation and use foundation waterproofing. In new construction, lay down a moisture barrier before pouring concrete slab floors.

Splashback on siding

Paint and seal bottom edge of siding. Install wedges to provide capillary break. Move soil away from foundation to provide 2-foot distance to siding if slope away from house can be maintained.

Blocked exterior air circulation

Cut back foliage to allow for circulation. Move stored items away from the house to avoid reducing circulation. Keep vents clean.

the house is an often overlooked first step. See page 8 for information on insulating attics, floors, and walls.

Spot ventilation. The first preventive and corrective action for kitchens and bathrooms is to install fan venting systems that pull moisture out quickly. The recommended minimum ventilation rate for bathrooms is 80 to 100 cubic feet per minute (cfm); and for kitchens, 150 cfm or more. To minimize the tendency of occupants to turn noisy fans off, bath fans should be rated at 2 sones or less. (A sone is a common industry measurement of noise level.) Bath fans should be connected to a crank or twist timer that allows the fan to operate for 15 to 30 minutes.

Always vent exhaust fans directly to the outside—do not dump the air into the attic, basement, crawl space, or garage. Extensive damage can result when moisture condenses on cold surfaces. Ductless kitchen and bath recirculating fans, although they may meet code, simply filter the air and do not remove any moisture.

Installing an exhaust fan in the ceiling and running duct to a vent on the roof or soffit is common. To reduce the amount of warm air that escapes through the bypass into the attic, seal all joints in the exhaust duct and gap where the fan housing meets the ceiling. Use at least 4" duct and run it to the roof or soffit vent—metal vents are more durable. Minimize the number of elbows in the duct run. Be sure the backdraft damper in the fan and vent, if it has one, operates freely.

Running the exhaust duct down an inside wall and venting the air out through the rim joist prevents cold air coming back through the duct.

Through-the-wall exhaust fans for bathrooms and kitchens also are available and may be easier to install, since no additional ducting or vents are needed. Exterior-mounted fans are much quieter, making them excellent for kitchen fan systems. Kitchen hoods should have a filter element to keep grease from accumulating in the duct work.

Some bathrooms have an overhead infrared heat lamp with a blower to help circulate the air. The heat lamps only reduce visible signs of condensation and increase comfort—they do not remove moisture. A ducted exhaust fan is a better solution.

Exhaust fans can cause problems with the proper venting of woodstoves, fireplaces, and gas or oil heating equipment. To check, turn on all exhaust fans and the appliance while holding a stick of burning incense where the flue connects to the equipment. If the smoke does not go up the chimney within 1 minute after the furnace or waterheater fires, have a heating contractor inspect the venting system.

Whole-house ventilation. If problems persist after other moisture control strategies are undertaken, you may wish to install a whole-house ventilation system to provide a controlled amount of fresh air. Whole-house ventilation may be the best strategy for controlling moisture in high-occupancy buildings such as apartments.

A whole-house ventilation system (Figure 4) consists of a very quiet, centrally located exhaust fan with air inlets to supply fresh air and a control to operate the fan at least 8 hours per day. The system should be sized to

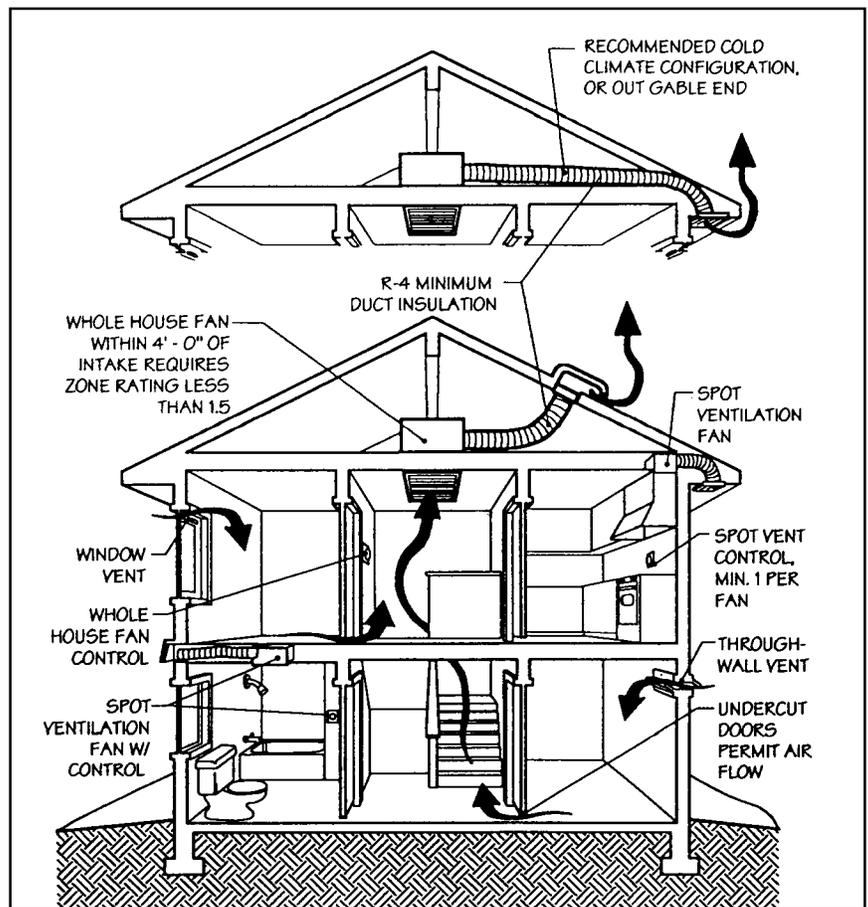


Figure 4.—Spot and whole-house ventilation, based on typical state code. (Courtesy Washington State Energy Office).

provide 30 cfm of air to the master bedroom and 15 cfm for each additional bedroom and main living area. The whole-house fan, which can double as a spot ventilator, must have the capacity to move sufficient air and be very quiet so occupants will not be tempted to shut the system off. Air inlets may be mounted through the wall or are available in many new windows. You must ensure air flow from the inlets in each room to the fan by undercutting interior doors, installing transom grilles, or another method to allow the air to flow between rooms.

Another option is a heat recovery ventilator, sometimes called an air-to-air heat exchanger. It transfers much of the heat from outgoing stale air to the fresh air coming into the house. Such units are centrally located and may have their own ductwork or be incorporated in a forced-air heating system. In cold climates, a heat exchanger must have an automatic defrost cycle to prevent condensation from blocking the exhaust air flow.

Fixing drainage problems

Excess surface water, high ground water table, and clay soils are common problems around foundations. When combined with poor construction details, drainage problems can quickly cause moisture problems throughout the house, from basement to roof. Tackle foundation water problems from the outside first.

Many drainage improvements are fairly simple, such as unclogging footing drains or adding downspouts and replacing flashing. Others are costly or require a lot of labor for retrofit applications, such as installing a sump pump or excavating around the basement walls to install a drain tile system, to get at the source of a severe ground water problem. Paint-on interior foundation coatings applied on the inside may be sufficient in some situations. If foundation drainage problems are not severe and repair would be expensive, installing a dehumidifier to control indoor humidity may be worth trying.

In some cases, installing a drain system around the perimeter of the basement floor is the only available option.

Even in systems where the foundation is tied into the drain tile system, a cement block wall still may be wet enough to allow a

significant amount of moisture to migrate up into the frame walls through capillary action.

Moving the soil around the foundation to achieve a good slope away from the house is a basic treatment. A 6-inch slope over a 5-foot run is recommended. Maintain a 2-foot clearance from the siding. Where cost or lack of space prohibit meeting the recommended slope, slope the soil as much as possible, and try to channel water away (Figure 1).

Downspouts should have a splash block or extension to channel water 3 to 5 feet away from the house. Ground-level drains also can be installed at the drip line. Inspect and repair flashing details all around the house.

Heavy rains may cause seasonal back-up of storm sewers, and if soil is heavy, it may retain water for long periods even though high ground water isn't normally a problem. In general, if the soil type is sandy and gravelly, and ground water is below the foundation level, natural drainage should be adequate.

Insulating attics, floors, and walls

Hidden moisture problems can be created when water vapor, usually carried by air movement, condenses inside building cavities such as attics and walls. This can lead to wood decay—commonly mislabeled “dry rot.” Water vapor moves into wall cavities both by air movement and by diffusion. However, most of the moisture is carried into building cavities by air leakage. Attics and crawl spaces are ventilated to remove any moisture that does get into the cavity.

Preventing the entry of moisture into these cavities by sealing air leaks from the inside of the house is the most effective way to minimize moisture problems in attics and walls. In some cases, moisture can be transferred from basements or crawl spaces through plumbing chases and wiring holes through interior walls. Sealing these bypasses will reduce moisture movement as well as heating costs.

Vapor barriers—correctly called vapor retarders—are installed to control the diffusion of moisture through a surface. These are commonly 6-mil polyethylene (“Visqueen™”) underneath the gypsum board, the kraft or foil backing of batt insulation, or vapor retarder paint or primer on the surface.

Attics. Eliminating air bypasses into the attic is the best strategy to avoid moisture problems in attics. Attic bypasses should be sealed before installing insulation. Seal around all penetrations into the attic, such as plumbing pipes, chimney chaseways, and electrical wiring. For more information, see *Finding and Fixing Hidden Air Leaks*, EC 1286 (ordering information on page 11).

Attics should be ventilated with passive vents located to promote good air circulation. Half of the vents should be placed high on the roof, at least 3 feet higher than the lower vents, which should be as close to the eaves as possible (Figure 5). Using a fan for attic ventilation is costly and can draw moisture and heated air into the attic.

When adding insulation to the attic, be sure the insulation doesn't block the vents. Cardboard or plastic baffles can be installed on the underside of roof sheathing to maintain at least 1 inch clearance allowing airflow. A common moisture problem occurs where the wall and ceiling meet below an attic. Depending on how the soffit vents are installed and the amount of insulation, cold ventilation air also may cool down interior surfaces at this junction, in turn causing persistent mold growth.

Use loose fill or unfaced batt insulation over any existing attic insulation, since the backing can act as an unwanted vapor barrier, possibly resulting in condensation inside the insulation.

Crawl spaces. A ground moisture barrier is needed to stop moisture migrating up from the soil into the crawl spaces. The moisture barrier usually is a tough, puncture-resistant material, often 6-mil polyethylene, laid over the soil and held in place with weights or bricks. For best protection, overlap the sheets of plastic about 12" and seal together with butyl rubber caulk or with tape designed to adhere to plastic sheeting. Do not allow the plastic to touch any wood framing. Storing household items and allowing pets in crawl spaces usually reduces the effectiveness of the ground moisture barrier.

The state building code requires at least 1 square foot of net free ventilation areas for each 150 square feet of under-floor area. Vent openings must be arranged to provide for cross ventilation, and must be distributed approximately evenly along two opposing sides. If there is an approved ground moisture barrier in place, building code officials

may reduce the amount of ventilation required to 1 square foot for each 1,500 square feet of under-floor area. Check with your local building code official. Crawl space vents should be closed in the winter and opened in the spring, summer, and fall.

Walls. Insulating walls of older homes is commonly done by blowing in cellulose or similar loose insulation into the cavities, usually through small holes drilled from the outside. Since the walls of older homes usually have been painted many times, it is unusual to have to retrofit a vapor barrier. Condensation problems usually are localized in an area of high moisture generation, such as the bathroom, or where there is air leakage from the house into the wall.

Seal all penetrations into the walls, such as around windows, doors, and electrical outlets and switches. Built-in cabinets and baseboards are other potential areas of condensation because of air leakage.

If the wall cavity will be open as part of a remodeling or renovation effort, a vapor barrier can be installed easily at that time. Vapor barrier paints, kraft or foil-faced batt insulation, or 6-mil polyethylene are appropriate.

Reducing window condensation

Since windows have such low insulation value, they are cold surfaces in the winter, causing many indoor condensation problems. They can be upgraded by adding a storm window or replacing the entire sash with double- or triple-pane sealed insulating units. Many new windows have an argon or krypton gas between the panes, or a coating called "low emissivity" or "low E," for even better insulation value.

Closing drapery, blinds, and shades at night can aggravate window condensation because they insulate the window surface from room heat, making it colder. Since most window coverings don't provide for a tight seal around the edges, room air can circulate next to the window and is more likely to condense.

When adding an outside storm window, make sure it has small weep holes at the

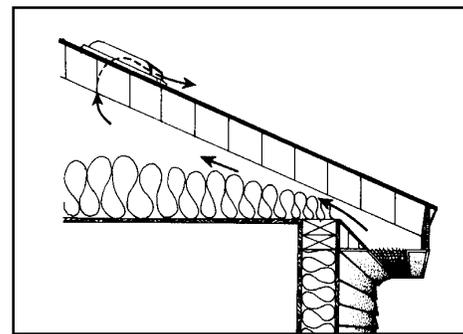


Figure 5.—Passive attic vents.

bottom to allow moisture to escape. Exterior storm windows should not be installed airtight. If the prime window does not fit as tightly as the storm window, condensation and light frost on an exterior storm window can occur. However, if the buildup is heavy and remains on the storm window for an extended period, it is probably a sign the prime window should be weatherstripped, or the indoor humidity is too high, or both.

With interior storm windows, make sure the seal is tight around all edges to reduce condensation problems. Newer interior window insulation products, such as the popular “shrink film” and “snap track” systems, provide a tight seal around all edges to reduce condensation problems.

Double-hung windows allow warm, moist air from inside the house to get next to the window through holes where the sash counterweight cord enters the wall, or along edges of the interior window trim. Caulk around both edges of the interior window trim where it meets the wall and window frame. Special covers can be used to seal the pulley holes, while allowing the cords to operate. You can use clear tape for a low-cost temporary seal.

Dehumidification

If humidity is still a problem after you’ve tried some of these moisture control strategies, another option is to dehumidify indoor air. This is common in basements.

Mechanical dehumidifiers remove moisture by cooling the air. Moist air is pulled past cooling coils and water vapor condenses on the coil, then drips into a collection pan. The drier air is then exhausted back into the house. Humidifiers can’t lower the indoor humidity levels much below 50 percent RH, a comfortable winter indoor humidity level.

At room temperatures of 65 °F or below, frost or ice can form on the cooling coils, and dehumidification stops until the unit is defrosted. Some units have an automatic defrost cycle. Others must be manually defrosted by shutting down the unit until the ice melts.

Select a dehumidifier with a permanent drain connection rated for at least 24 pints of water per day. Install the dehumidifier so there is good air circulation around the front of it. Since the humidity level will equalize throughout the house, the unit does not have to be centrally located as long as interior doors are open. Select a location near a drain so you don’t have to empty the condensate pan. Or connect a hose from the unit through a hole in the floor to a drain in the basement. For best efficiency, check and clean dust from the coils monthly. If your unit is not plumbed, empty and clean the drainage pan regularly. Stagnant water can grow mold and bacteria, and be a health hazard.

Chemical dehumidifying agents, known as “desiccants,” absorb moisture in the air. Desiccants may be an option for slight problems confined to small areas like closets. But they can be dangerous to children and pets. Some desiccants are corrosive and must be handled with extreme care. Others are reusable and nontoxic, but you should wash your hands thoroughly after handling even the nontoxic variety.

Remember that dehumidification, whether mechanical or chemical, is treating the symptom and not the problem. Dehumidify only if you cannot solve the problem by reducing the amount of moisture in your home.

Avoiding condensation on inside surfaces

at 20°F outside, 70°F inside temperatures

	Inside surface temperature	Maximum indoor Relative Humidity (RH) to avoid condensation
Walls/ceiling¹		
2x 4 uninsulated	58°F	65% RH
R-11 insulation	67°	90%
R-19 insulation	68°	90%
Windows²		
single pane (U-1.13)	31°	20%
storm/double pane (U-0.55)	51°	50%
triple/low-E (U-0.36)	57°	65%

¹RH recommendations do not take into account surface cooling at localized air leakage sites.

²Since glass temperatures are colder near edges, condensation may occur there at much lower RH for storm/double and triple/low-E windows.

Source: Axel Carlsen, Extension engineer, University of Alaska.

Paint problems

Peeling, blistering, or cracking exterior paint can point to an indoor moisture problem, especially if the raw surface or wood is visible. Often, paint problems are severe on outside walls of rooms with high humidity, such as bathrooms or rooms with major air leakage.

Some paint problems are not recognized as being caused by interior moisture, and the problem is simply covered up with a new coat of paint or new siding. Of course, some paint problems are caused by poor surface preparation or application, or use of a paint that wasn't meant for a particular job.

For further reading

Finding and Fixing Hidden Air Leaks, EC 1286.

No charge. (See ordering instructions below.)

How to Prevent and Remove Mildew in the Home, EC 1174. \$1.00. (See ordering instructions below.)

"Wood Fungi: Causes and Cures," by Stephen Smulski, *Journal of Light Construction*, May 1993, pp. 15-19.

Ordering instructions: To order EC 1174, *How to Prevent and Remove Mildew in the Home*, EC 1286, *Finding and Fixing Hidden Air Leaks*, or additional copies of EC 1437, *Home moisture problems*, send the amount shown to:

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Wood deterioration

Decayed wood is more permeable to moisture and more subject to further damage and decay. Recognizing wood decay is a skill that comes with practice, but several symptoms stand out.

White rot is probably the worst form of wood decay, and often the most difficult to recognize. Wood infected with white rot appears somewhat whiter than normal, sometimes with dark lines bordering the light discoloration. Because the wood doesn't visibly shrink or collapse, people sometimes miss the fact that wood with white rot is seriously weakened and possibly ready to collapse. In advanced stages, some cracking across the grain occurs.

In contrast, **brown rot** readily shows as a brown color or brown streaks on the face or end grains. In advanced stages, the wood appears damaged, with cracks across the grain, and the surface shrinking and collapsing.

White and brown rot are serious forms of wood decay that deserve treatment or wood replacement.

Soft rot and **blue stain** are less damaging forms of wood decay that tend to be more active on the surface. Soft rot is recognizable because the wood surface appears soft and profusely cracked, resembling driftwood in color. Soft rot decay is slower acting than white or brown rot. Blue stain indicates somewhat weakened wood, with a blue, brownish black, or steel-gray colored staining. The discoloration actually penetrates the wood cells and is not a surface stain.

Household moisture sources

Moisture source	Estimated amount (pints)
Bathing:	
tub (excludes towels and spillage)	0.12/standard size bath
shower (excludes towels and spillage)	0.52/5-minute shower
Clothes washing (automatic, lid closed, standpipe discharge)	
0+ /load (usually nil)	
Clothes drying:	
vented outdoors	0+ /load (usually nil)
not vented outdoors, or indoor line drying	4.68 to 6.18/load (more if gas dryer)
Combustion (unvented kerosene space heater)	
7.6/gallon of kerosene burned	
Cooking:	
breakfast (family of four, average)	0.35 (plus 0.58 if cooking with gas)
lunch (family of four, average)	0.53 (plus 0.68 if cooking with gas)
dinner (family of four, average)	1.22 (plus 1.58 if cooking with gas)
simmer at 203°F, 10 minutes, 6-inch pan	less than 0.01 if covered, 0.13 if uncovered
boil 10 minutes, 6-inch pan	0.48 if covered, 0.57 if uncovered
Dishwashing:	
breakfast (family of four, average)	0.21
lunch (family of four, average)	0.16
dinner (family of four, average)	0.68
Firewood storage indoors (cord of green firewood)	
400 to 800/6 months	
Floor mopping	
0.03/square foot	
Gas range pilot light (each)	
0.37 or less/day	
House plants (five to seven average plants)	
0.86 to 0.96/day	
Humidifiers	
0 to 120+ /day (2.08 average/hour)	
Respiration and perspiration (family of four, average)	
0.44/hour (family of four, average)	
Refrigerator defrost	
1.03/day (average)	
Saunas, steambaths, and whirlpools	
0 to 2.7+ /hour	
Combustion exhaust gas backdrafting or spillage	
0 to 6,720+ /year	
Evaporation from building materials:	
seasonal	6.33 to 16.91/average day
new construction	10+ /average day
Ground moisture migration	
0 to 105/day	
Seasonal high outdoor humidity	
64 to 249+ /day	

Source: Minnesota Extension Service, University of Minnesota.



Adapted from *Home Moisture Problems*, by the Minnesota Department of Public Service; and *Moisture and Home Energy Conservation*, by the National Center for Appropriate Technology. Prepared with the support of the U.S. Department of Energy, Grant No. DE-FG02-76CS60014. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author and do not necessarily reflect the view of the Department of Energy.



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